NAE20:0, with the compounds NAE10:0, NAE12:0, NAE14:0, NAE16:0, NAE18:0 and NAE 20:0 being particularly preferred.

Exemplary unsaturated NAE compounds include, for example, NAE10:1, NAE10:2, NAE10:3, NAE10:4, NAE10:5, NAE10:6, NAE11:1, NAE11:2, NAE11:3, NAE11:4, NAE11:5, NAE11:6, NAE12:1, NAE12:2, NAE12:3, NAE12:4, NAE12:5, NAE12:6, NAE13:1, NAE13:2, NAE13:3, NAE13:4, NAE13:5, NAE13:6, NAE14:1, NAE14:2, NAE14:3, NAE14:4, NAE14:5, NAE14:6, NAE15:1, NAE15:2, NAE15:3, NAE15:4, NAE15:5, NAE15:6, NAE16:1, NAE16:2, NAE16:3, NAE16:4, NAE16:5, NAE16:6, NAE17:1, NAE17:2, NAE17:3, NAE17:4, NAE17:5, NAE17:6, NAE18:1, NAE18:2, NAE18:3, NAE18:4, NAE18:5, NAE18:6, NAE19:1, NAE19:2, NAE19:3, NAE19:4, NAE19:5, NAE19:6, NAE20:1, NAE20:2, NAE20:3, NAE20:4, NAE20:5, and NAE20:6. More preferably, the unsaturated NAE compounds are selected from the group consisting of NAE10:1, NAE10:2, NAE11:1, NAE11:2, NAE11:3, NAE12:1, NAE12:2, NAE12:3, NAE13:1, NAE13:2, NAE13:3, NAE14:1, NAE14:2, NAE14:3, NAE15:1, NAE15:2, NAE15:3, NAE16:1, NAE16:2, and NAE16:3, which are more soluble in aqueous solution ~~than the longer-chain, and more highly unsaturated NAE compounds~~.

The compounds of the present invention are preferably formulated in aqueous solutions, and may optionally further comprise a nutrient source, such as a lipid, a sugar, or an amino acid, or a carbohydrate, such as lactose, dextrose, fructose, sucrose, glucose sorbitol, mannitol, or inositol.

The compositions and formulations of the anti-senescent compounds of the invention may also further optionally comprise a surfactant, such as polyoxyethylene sorbitan monolaurate, monopalmitate monostearate, ethoxylated alkyl phenols or hydrogenated oils, and may also further optionally comprise one or more salts or buffering agents as described below. Exemplary buffers for use in formulating the compounds of the invention include, but are not limited to, acetate, bicarbonate, citrate, succinate, malate, TRIS (Tris-(hydroxymethyl)-aminomethane), MES (2-[N-Morpholino]-ethanesulfonic acid), HEPES (N-[2-hydroxyethyl]piperazine-N'-[2-ethanesulfonic acid]), MOPS (3-(N-Morpholino)-propanesulfonic acid), BES (N,N-Bis-(2-hydroxyethyl)-2-aminoethanesulfonic acid), and BIS-TRIS (Bis-(2-hydroxyethyl)-imino-tris-(hydroxymethyl)-methane).

As described below, the composition may further optionally comprise one or more osmoregulants, such as a salt, a carbohydrate, a polyol, or a polyethylene glycol. Likewise, they may contain one or more plant hormones such as auxins, gibberellins and cytokinins.

In related embodiments, the formulations of the active ingredients of the invention may further optionally comprise one or more antifungal, bacteriostatic, or bactericidal agents

such as 8-hydroxyquinoline citrate, sodium dichloroisocyanurate, or 1,3-dichloro-5,5-dimethyhydantoin in an amount sufficient to retard or inhibit the growth of fungi or bacteria in the prepared solutions.

The formulations of the anti-senescent compounds may further comprise an alcohol, such as ethanol or isopropanol, particularly when manufacturing concentrated or stock solutions of the formulation, which may later be diluted as needed to prepare the final working solutions used to treat the plant or plant cuttings.

The compositions may also further optionally contain a second anti-senescent component. This component may be another distinct N-acylethanolamine compound (such as those described herein), or may be a commercially-available anti-senescent cut flower nutrient or preservative component such as Petalife® (8-hydroxyquinoline citrate), Oasis® (Smither's Oasis, Inc., Kent, OH), Rogard® (Gard Environmental Group, Carpentersville, IL), Everbloom® (8-hydroxyquinoline citrate), FloraLife® (Floralife, Inc., Walterboro, SC), Vita Flora® (Vita Products, Inc., Chandler, AZ), Aquaplus® (Syndicate Sales Inc., Kokomo, IN), Spring®, or Crystal Clear™ (Floralife, Inc., Walterboro, SC).

The invention also provides kits, typically packaged for wholesale, or retail distribution, that comprise the active NAE compound, or compositions or formulations thereof, along with suitable instructions for using the formulations to delay the senescence of a flower, fruit, or severed plant part. These kits may include, for example, measuring devices, applicators, measuring droppers, or other suitable means for applying or diluting the aqueous solution to the final appropriate concentration, or for directly administering the active ingredients to either a plant under cultivation, or to the flowers, fruit, or plant parts post-harvest.

In another embodiment, the invention provides methods of use of the disclosed compounds, compositions, formulations, and kits, in the treatment of cut flowers, fruits, severed plant parts, or ornamental plant cuttings to prolong their senescence, and to extend their shelf life, appearance, or other aesthetic qualities. These methods generally involve providing to the plant, fruit, or plant part, an effective amount of a solution that comprises a senescence-delaying amount of a compound of the formula:

$$RCONHCH_2CH_2OH$$

where R is optionally branched or straight chain, saturated or unsaturated C_8-C_{20} alkyl; or a composition that comprises such a compound, and a horticulturally acceptable vehicle.

alcohol sulfates, phosphate esters, N-cylsarcosinates, alkyl monoglyceride sulfates, N-acyl methyltaurates, α-olefinsulfonates, polyalkoxycarboxylates and alkyl sulfoacetates.

The desired effects of the disclosed compositions may also be enhanced by the addition of small amounts of a wetting agent. For example, non-ionic surfactants such as "Tween," or other polyoxyethylene derivatives of hexitol anhydride partial long chain fatty acid esters, have been found to be especially suitable. The wetting agent must be compatible with the other ingredients of the composition and must not adversely affect plant life. The quantity of wetting agent must be limited, since too much wetting agent has been found to prevent absorption by the flower stem, resulting in rapid wilting. With wetting agents of the "Tween" type, the upper limit is typically on the order of about 20 to 25 ppm with lesser amounts often providing more desirable results. The wetting agent also insures that the water-conducting vessels and tissues of the flower stem will remain open in order for the blossoms to draw nutrient when necessary. In the NAE formulations described herein, the inventors have found that the concentration of Tween-20™ (polyoxyethylenesorbitan monolaurate), *e.g.*, could be varied on the order of from about 0.001 ml/ml of alcohol to about 0.01 mL/mL of alcohol in concentrated solutions, without diminished results on final NAE solubility in reconstituted aqueous working solutions, or on the efficacy in tests with cut flowers.

The compositions of the present invention may also contain one or more plant hormones. Suitable plant hormones include, for example, auxin, cytokinin, gibberellin, brassinolide and the like. The content of the plant hormones in the preservative may be optionally varied depending upon the particular hormone used and other factors. However, generally, if added, the plant hormone is preferably used in the preservative in an amount of about 0.03% by weight or less in terms of the concentration of the hormone in the water used for the cut flowers. In certain circumstances, the hormone may be present in an an amount of about 0.02% by weight or less in terms of the concentration of the hormone in the water used for the cut flowers, while in certain embodiments, the hormone may be present in an amount of about 0.01% by weight or less.

The compositions described herein may further optionally comprise an additional anti-senecent compound, such as, *e.g.*, acetylsalicylic acid, acetylsalicylsalicylic acid, or derivatives thereof, in an amount sufficient to enhance water uptake by the cut flowers or plant parts. For example, addition of acetylsalicylic acid or acetylsalicylsalicylic acid in an

To prepare working solutions, this stock solution may be diluted in an aqueous solution to the desired final concentration of NAE. Working solutions have been prepared and tested in the range of from about 3.5 mg/L to about 100 mg/L final concentration of NAE. In one such embodiment, a final working concentration of the anti-senescent ingredient on the order of about 12.5 mg/L has shown to be particularly advantageous in the preservation of several floral crops. Additionally, one or more wetting agents may be added to the solutions to improve ease of formulation.

Other NAEs such as those described herein, and particularly NAE's such as NAE14:0, NAE16:0, NAE18:0, NAE 18:1, and NAE18:2 have been shown to effectively substitute for NAE12:0 in the formulation shown above, particularly in terms of solubility (in aqueous solutions) and efficacy. These NAEs, however, may be less desirable in certain embodiments due to typically higher manufacturing costs and decreased shelf life. The use of longer acyl chain NAEs such as NAE16:0, NAE18:0 and NAE20:0 in the formulations of the invention may also be less desirable due to their limited solubility in water (*e.g.*, visible turbidity is apparent in some NAEs at concentrations as low as 17.5 mg/L). Nonetheless, formulations containing these NAEs were effective at extending the freshness of cut roses beyond that of water alone, or commercial preservative solutions such as FloraLife®.

The formulations may optionally be prepared in ordinary water, distilled water, deionized water, or reverse osmosis purified water alone, or alternatively, may be prepared as buffered aqueous solutions as described above. For example, formulations of about 10 to 20 mM potassium phosphate in a pH range of from about 6.5 to about 8.0; or alternatively, formulations of about 10 mM to 50 mM $NaHCO_3$, in a pH range of from about 7.0 to about 8.0, have been shown to provide particular advantages in the preservation of many types of floral and foliage cuttings.

Moreover, the inventors have demonstrated the ability of the compounds and compositions of the present invention to be readily added to many of the commercially available flower and ornamental tree formulations. For example, the NAE compositions disclosed herein, such as, for example, NF20-XL, dissolve readily in the commercially available nutritive solutions such as Peters Professional Christmas Tree Preservative (Spectrum Brands, Inc. St. Louis, MO), Petalife® (8-hydroxyquinoline citrate), Oasis® (Smither's Oasis, Inc., Kent, OH), Rogard® (Gard Environmental Group, Carpentersville, IL), Everbloom® (8-hydroxyquinoline citrate), Aquaplus® (Syndicate Sales Inc., Kokomo, IN), Spring®, Vita Flora® (Vita Products, Inc., Chandler, AZ), and Chrysal Clear® (Pokon

& Chrysal-Naarden-Holand, Bussum, The Netherlands) or Floralife® (FloraLife, Inc., Walterboro, NC).

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The inventors have also tested several different types of powdered and fluidized lecithin products from central soya in various NAE formulations. All were shown not to interfere with effectiveness of the active ingredients, and enzyme-modified and hydroxylated lecithins afforded significant increased solubility of the NAE compounds when alcohol-concentrated stock solutions were diluted into aqueous working solutions when compared to solutions containing unmodified lecithins, or no lecithins at all.

The inventors also contemplate that in certain aspects of the invention it may be advantageous or desirable to optionally prepare the anti-senescent formulations using a combination of two or more active ingredients. In these embodiments, the active ingredients could comprise two or more NAE compounds present in similar, or different concentrations, or alternatively, could comprise one NAE compound in combination with one or more additional anti-senescent or flower-preserving active ingredients. For example, one or more NAE compounds could be added to commercial formulations already demonstrated to possess flower-preserving or flower appearance-extending properties to provide an enhanced or synergistic amount of flower-preserving activity than that afforded by the use of just one such compound alone. Owing to the preparation and manufacture of the many commercially-available formulations of ornamental tree freshness products, and the equally large number of commercially-available formulations of cut flower preserving and enhancing products, the inventors contemplate that significant advantages could be obtained by adding one or more of the NAE compounds disclosed herein to such formulas to provide improved products that significantly prolong the freshness, appearance, and aesthetic qualities of flowers and plant parts contacted with such solutions.

2.4 Preparation of the Compositions of the Invention

The cut flower preservative composition of the present invention can be prepared by simply mixing the components necessary to complete the intended preservative in accordance with conventional mixing technologies. To prepared diluted NAE compositions, water and/or other suitable solvents or diluents may be used in suitable proportions. For example, the NAE compound(s) may be formulated in water or water-soluble organic solvents (for example alcohols, glycols or glycerol) or other suitable carriers or diluents.